UTILIZATION OF WASTE

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ELECTROPLASMA FACILITY FOR OBTAINING MINERAL FIBER FROM REFRACTORY SILICATE-CONTAINING MATERIALS

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A fundamentally new facility for obtaining mineral fiber from refractory silicate materials using highly concentrated heat flows is examined. The working regimes and thermophysical parameters of a plasma-chemical reactor are determined. The performance characteristics of fiber obtained using the facility and the conventional technology are compared.

The demand for building materials, including heat-insulating, in the industrial sector is continually rising. The existing technologies for producing mineral fiber, based on obtaining first a melt of the natural raw material — basalt, diabase, gabbro, diorite, which are characterized by a relatively low melting temperature (down to 1500°C), are preferable from the standpoint of energy. However, a not inconsequential factor which holds back production is that the fuel (for example, coke) and raw materials used are expensive. This problem can be solved by using plasma technologies and by expanding the raw materials base using wastes from the energy and mining industries. Such wastes comprise a mineral residue containing 35 – 60% SiO_2 and are characterized by a high (1600 – 2200°C) melting temperature.

As a result of the high temperature with which it acts on materials — (3 – 5) × 10^3°C, the use of a highly concentrated low-temperature plasma flow as the source of heat sharply decreases the likelihood of emissions of underoxidized components. In addition, the melt formation time decreases (practically, to several seconds) and the induction period for melting, which presents the greatest ecological hazard, is eliminated.

It should be noted that plasma processes are essentially non-inertial. They can be easily controlled and they are easier to automate. In addition, the final product is obtained in one stage [1].

Thus, plasma technologies for obtaining scarce materials for the building industry, such as mineral wool, will make it possible to organize economical production and to solve a host of ecological problems.

The purpose of the present work is to develop a combined source of heat (plasma – joule heating) for obtaining melt from refractory silicate-containing materials and to determine its thermophysical parameters as well as to clarify the possibility of obtaining mineral fiber from the melt.

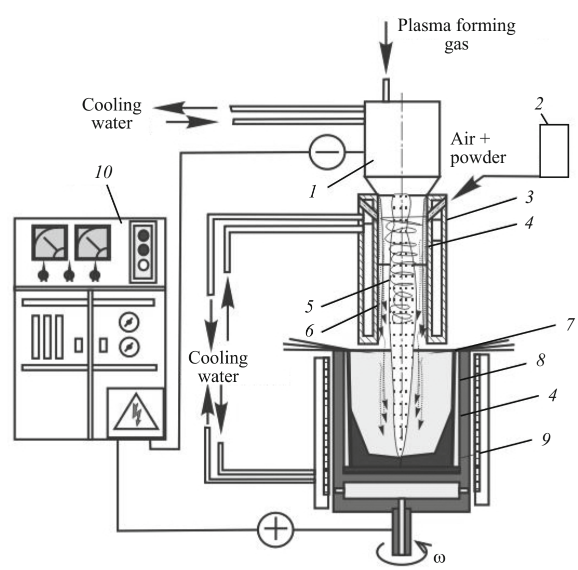

Fig. 1. Diagram of the experimental facility with a combined source of heat for obtaining mineral fiber: *1*) plasmatron; *2*) apparatus for dispensing the raw materials; *3*) heat concentrator; *4*) cover layer; *5*) plasma arc; *6*) melt; *7*) mineral fiber; *8*) rotating reactor; *9*) melt pool; *10*) power supply.

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TABLE 1.

Regime	Plasmatron power, kW	Current strength, kA	Voltage, V	Specific heat flux, 10^6 W/m^2
1	24	140	170	1.1
2	35	220	160	1.8
3	56	400	140	2.6

Combustible shales, which are used as an energy fuel in industry, and a topaz component, which serves as a raw material for the production of mullite and mullite articles, were chosen as the raw materials.

Mineral fiber was obtained from melt of refractory silicate-containing materials on an electroplasma setup (Fig. 1). This setup consists of the following basic units: an up to 120 kW APR-404 dc source; a plasmatron for the external region of energy release; a heat concentrator in the form of a water-cooled cylinder; a dispensing apparatus for feeding the disperse material; and, a rotating reactor with a graphite anode (RF Claim No. 2007123894) mounted on the bottom.

The operating principle of the facility is based on the interaction of highly concentrated plasma flows with a raw material in powder form (tailings of combustible shales, topaz ores). The powder material, fed through tangentially under the action of highly concentrated plasma flows, is atomized and flows to the bottom of the rotating reactor, forming a melt pool, which at high temperatures is electrically conducting; correspondingly, the arc discharge current of the plasmatron flows through the melt, which fully homogenizes the melt. As a result of the rotation of the reactor, the melt rises in the form of a film on the wall of the reactor under the action of centrifugal forces and, detaching from the edge of the reactor, is drawn into a fiber.

The initial working regimes of the electroplasma generator and the thermophysical parameters of the arc discharge are presented in Table 1.

The optimal regimes, where specific fluxes 1.8×10^6 and 2.6×10^6 W/m^2 were realized, for obtaining mineral fiber were established in the course of the experiments.

Chemical, x-ray phase, and microscopic analyses were performed to evaluate the characteristics of the initial raw materials. Chemical analysis showed that silicon and aluminum oxides predominate in them (Table 2).

The phase transformations occurring together with dissociation at high temperatures were studied on the basis of data obtained from x-ray phase analysis of a topaz concentrator, hot shale, and glass fiber. The x-ray photographs obtained show that the topaz concentrate consists primarily of topaz ($d = 3.20$, 2.96, 1.65, 1.37), quartz ($d = 1.86$, 1.52), and aluminosilicates such as kainite and sillimanite. The hot-shale wastes are represented by quartz (d = 5.15, 4.52, 3.81, 1.82), aluminosilicates ($d = 3.37$, 2.81, and 2.51), and anortite ($d = 2.13$). The data from x-ray phase analysis of the glass fiber show that the fiber is represented by a glass phase and is x-ray amorphous [2].

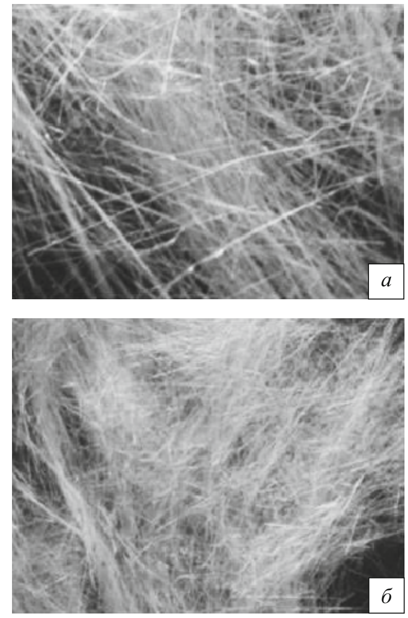

Fig. 2. Photomicrograph of a mineral fiber (× 300) from hot-shale wastes, specific heat flux 1.8×10^6 W/m^2 (*a*), and from topaz concentrate, specific heat flux 2.6×10^6 W/m^2 (*b*).

A difference along the thickness of the fiber can be seen in the photomicrographs (Fig. 2). This is due to, first and foremost, the use of different specific heat fluxes, where for high heat fluxes the temperature of the melt increases and, correspondingly the viscosity of the melt decreases and the conditions for obtaining a finer fiber improve (see Fig. 2*b*).

In Table 3, the properties of the fiber obtained with the plasma technology are compared with those of the obtained by the conventional technology.

As one can see, the quality of the mineral fiber obtained meets the requirements (GOST 4640–93) for mineral wool. Its distinguishing features are a high modulus of acidity, water resistance, and length.

TABLE 2.

Material	Mass content, %					Acidity module	Melting temperature, °C
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO		
Hot-shale wastes	61.59	23.36	7.91	1.60	1.27	29.59	1800 – 1900
Topaz concentrate	39.52	47.43	–	5.60	2.00	11.44	1830 – 1930

TABLE 3.

Indicator	Mineral fiber (plasma method)		Mineral fiber (cupola furnace method)
	from hot-shale wastes	from topaz concentrate	
Acidity modulus	< 29.59	8.74	< 1.60
Water resistance, pH	6 – 8	7 – 9	4
Fiber thickness, μm	4 – 7	3 – 5	6
Content of nonfiber inclusions, %	13	15	12
Fiber length, mm	50 – 110	100 – 120	25
Rupture strength, MPa	12 – 14	15 – 17	10 – 12

In summary, the hot-shale wastes and the topaz concentrate can be used to obtain mineral fiber using low-temperature plasma. This technology is characterized by the following:

low energy consumption — 1.5 – 3.0 kW · h per 1 kg of glass mass melt;

high degree of protection from contamination of the environment — low release of carbon monoxide and carbon dioxide;

high performance of the final product.

REFERENCES

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